CLAIMS

The following is claimed:

1. A method of changing a physical property of a structure, comprising:

providing energy of a first energy type to a structure by performing a first energy process according to an operational setting, at least one of the operational setting and a time value being selected according to a first order rate relationship for the first energy process, according to a first order rate relationship for a second energy process, and according to a desired physical property value; and

providing energy of a second energy type to the structure at an energy level above an activation energy for the structure by performing the second energy process;

wherein the first and second energy processes are performed concurrently for at least the time value;

wherein the first order rate relationship for the first energy process relates application of the first energy type to the structure and a physical property of the structure; and

wherein the first order rate relationship for the second energy process relates application of the second energy type to the structure and the physical property.

2. The method of claim 1, wherein the first energy type is thermal and wherein the second energy type is oscillatory.

3. The method of claim 2, wherein the operational setting is a temperature setting, wherein one of the temperature setting and the time value is selected according to the first order rate relationship for the first energy process, according to the first order rate relationship for the second energy process, according to the desired physical property value, and according to the other one of the temperature setting and the time value.

4. The method of claim 3, wherein the first order rate relationship for the first energy process is a first Larson-Miller relationship that relates application of thermal energy to the structure and the physical property, and wherein the first order rate relationship for the second energy process is a second Larson-Miller relationship that relates application of oscillatory energy to the structure and the physical property.

5. The method of claim 4, further comprising:

determining a first Larson-Miller parameter according the first Larson-Miller relationship, the first Larson-Miller parameter corresponding to the desired physical property value;

determining a second Larson-Miller parameter according to the second Larson-Miller relationship, the second Larson-Miller parameter corresponding to the desired physical property value;

selecting a first one of the temperature setting and the time value;

selecting a second one of the temperature setting and the time value according to the first and second Larson-Miller parameters, according to the first Larson-Miller relationship, and according to the first one of the temperature setting and the time value.

6. The method of claim 5, further comprising determining a third Larson-Miller parameter according to the first and second Larson-Miller parameters, wherein the second one of the temperature setting and the time value is selected according to the third Larson-Miller parameter, according to the first Larson-Miller relationship, and according to the first one of the temperature setting and the time value.

7. The method of claim 6, wherein determining the third Larson-Miller parameter comprises subtracting the second Larson-Miller parameter from the first Larson-Miller parameter.

8. The method of claim 7, wherein selecting the second one of the temperature setting and the time value comprises evaluating the first Larson-Miller relationship using the third Larson-Miller parameter and the first one of the temperature setting and the time value to obtain the second one of the temperature setting and the time value.

9. The method of claim 4, wherein the physical property is internal stress, and wherein the desired physical property value is one of a remaining internal stress value and an internal stress reduction value.

10. The method of claim 1, wherein the physical property is internal stress, and wherein the desired physical property value is one of a remaining internal stress value and an internal stress reduction value.

11. The method of claim 1, wherein the first order rate relationship for the first energy process is a first Larson-Miller relationship that relates application

of the first energy type to the structure and the physical property, and wherein the first order rate relationship for the second energy process is a second Larson-Miller relationship that relates application of the second energy type to the structure and the physical property.

12. The method of claim 11, further comprising:

determining a first Larson-Miller parameter according the first Larson-Miller relationship, the first Larson-Miller parameter corresponding to the desired physical property value;

determining a second Larson-Miller parameter according to the second Larson-Miller relationship, the second Larson-Miller parameter corresponding to the desired physical property value;

selecting a first one of the operational setting and the time value;

selecting a second one of the operational setting and the time value according to the first and second Larson-Miller parameters, according to the first Larson-Miller relationship, and according to the first one of the operational setting and the time value.

13. The method of claim 12, further comprising determining a third Larson-Miller parameter by subtracting the second Larson-Miller parameter from the first Larson-Miller parameter, wherein the second one of the operational setting and the time value is selected according to the third Larson-Miller parameter, according to the first Larson-Miller relationship, and according to the first one of the operational setting and the time value.

14. The method of claim 13, wherein selecting the second one of the operational setting and the time value comprises evaluating the first Larson-Miller

relationship using the third Larson-Miller parameter and the first one of the operational setting and the time value to obtain the second one of the operational setting and the time value.

15. The method of claim 1, wherein the second energy type is oscillatory, wherein the second energy type is provided to the structure at a frequency selected according to a resonant frequency of a system in which the structure is mounted while performing the first and second energy processes.

16. The method of claim 15, wherein the second energy type is provided to the structure at a frequency at or near the resonant frequency of the system.

17. The method of claim 1, wherein the second energy type is selected from the group consisting of sonic, laser, electrical, magnetic, mechanical vibration, and microwave.

18. A method of changing a physical property of a structure, comprising:

providing energy of a first energy type to a structure by performing a first energy process according to an operational setting; and

providing energy of a second energy type to the structure at an energy level above an activation energy for the structure by performing a second energy process;

wherein the first and second energy processes are performed concurrently for at least a time value; and

wherein one of the operational setting and the time value are selected according to a desired physical property value and according to a first order rate relationship that relates concurrent application of the first and second energy types to the structure and a physical property of the structure.

19. The method of claim 18, further comprising determining the Larson-Miller relationship that relates concurrent application of the first and second energy types to the structure and the physical property of the structure.

20. A method of stress-relieving a structure, comprising:

determining a first Larson-Miller relationship that relates application of thermal energy to the structure and internal stress in the structure;

determining a second Larson-Miller relationship that relates application of oscillatory energy to the structure and the internal stress in the structure;

determining a first Larson-Miller parameter according the first Larson-Miller relationship and according to a desired internal stress value for the structure;

determining a second Larson-Miller parameter according to the second Larson-Miller relationship and according to the desired internal stress value;

determining a third Larson-Miller parameter according to the first and second Larson-Miller parameters by subtracting the second Larson-Miller parameter from the first Larson-Miller parameter;

selecting a first one of a temperature setting and a time value;

selecting a second one of the temperature setting and the time value according to the third Larson-Miller parameter, according to the first Larson-Miller relationship, and according to the first one of the temperature setting and the time value;

selecting one or more oscillatory operational settings according to a resonant frequency of a system in which the structure is mounted;

providing thermal energy to the structure according the thermal operational settings; and

concurrently providing oscillatory energy to the structure according to the oscillatory operational settings for a time greater than or equal to the time value.

21. The method of claim 20, wherein selecting the second one of the temperature setting and the time value comprises solving a first Larson-Miller equation for the second one of the temperature setting and the time value first one of the temperature setting and the time value and the third Larson-Miller parameter, wherein the first Larson-Miller equation represents the first Larson-Miller relationship.

22. A method of determining operational settings and time values for concurrent application of multiple energy types to a structure to change a physical property of the structure, the method comprising:

determining a first parameter according to a desired physical property value for the structure and according to a first order rate relationship for a first energy process that relates application of a first energy type to the structure and the physical property;

determining a second parameter according the desired physical property value and according to a first order rate relationship for a second energy process that relates application of a second energy type to the structure and the physical property;

selecting a first one of a time value and an operational setting for the first energy process;

selecting a second one of the time value and the operational setting according to the first and second parameters, according to the first order rate relationship for the first energy process, and according to the first one of the time value and the operational setting.

23. The method of claim 22, further comprising:

determining the first order rate relationship for the first energy process; and

determining the first order rate relationship for the second energy process.

24. The method of claim 22, wherein the first order rate relationship for the first energy process is a first Larson-Miller relationship that relates application of the first energy type to the structure and the physical property, and wherein the first order rate relationship for the second energy process is a second Larson-Miller relationship that relates application of the second energy type to the structure and the physical property.

25. The method of claim 22, further comprising determining a third parameter according to the first and second, wherein the second one of the time value and the operational setting is selected according to the third parameter, according to the first order rate relationship for the first energy process, and according to the first one of the time value and the operational setting.

26. The method of claim 25, wherein determining the third parameter comprises subtracting the second parameter from the first parameter.

27. The method of claim 25, wherein selecting the second one of the time value and the operational setting comprises evaluating the first order rate relationship for the first energy process using the third parameter and the first one of the time value and the operational setting to obtain the second one of the time value and the operational setting.

28. The method of claim 22, wherein the physical property is internal stress, and wherein the desired physical property value is one of a remaining internal stress value and an internal stress reduction value.

29. A method of determining operational settings for concurrent application of multiple energy types to a structure to change a physical property of a structure, the method comprising:

determining a first order rate relationship that relates concurrent application of first and second energy types to the structure and a physical property of the structure;

determining a first order rate parameter according to the first order rate relationship, the first order rate parameter corresponding to a desired physical property value for the structure;

selecting a first one of an operational setting for the first energy process and a time value; and

selecting a second one of the operational setting and the time value according to the first order rate parameter, according to the first order rate relationship, and according to the first one of the operational setting and the time value.

30. The method of claim 29, further comprising determining the first

order rate relationship that relates concurrent application of first and second energy types to the structure and a physical property of the structure.

31. A system for changing a property of a structure, comprising:

a thermal energy source;

an oscillatory energy source; and

a control system that provides control signals to the thermal and oscillatory energy sources to control concurrent delivery of thermal and oscillatory energy from the thermal energy source and the oscillatory energy source to a structure.

32. The system of claim 31, further comprising transducers operatively coupled with the structure to provide feedback signals to the control system 180.